PATENT SPECIFICATION

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(54) OPTICAL OBJECTIVES

(71) We, THE RANK ORGANISATION LIMITED, of 11 Hill Street, London W1X 8AE, a British Company, formerly of Millbank Tower, Millbank, London, S.W.1, do hereby declare the invention, for which we pray that a patent may be granted to us, and the method by which it is to be performed, to be particularly described in and by the following statement:—

This invention relates to an optical objective, more particularly to an optical objective of the type commonly known as the Petzval type, which comprises front and rear positive lens groups axially separated by an air space, not containing any lens components, of not less than 0.75F, where F is the equivalent focal length of the complete objective.

There is a requirement in various fields for objectives having a high specification, for example an F-number of the order of 1.2 to 0.9 with a substantial entrance pupil of at least 150 mm. covering a field of ±4 to ±5 degrees, wherein all aberrations over a large waveband are well corrected, particularly those arising due to the secondary spectrum (difference in focus for light at the two extreme ends of the waveband to be covered as compared with the focal plane at the centre of the waveband).

In the prior art, a major limitation of known refracting objectives attempting to provide such a high specification, in particular large aperture and wide operating waveband, has been aberrations arising from the secondary spectrum. Glass materials having anomalous dispersion characteristics have been employed, but these create difficulties in correction of primary monochromatic aberrations. In consequence, catadioptric objectives have been designed to achieve the high specification required, but these are disadvantageous in demanding substantially greater diameter than their refracting counterparts, in order to make up for loss of use of their central zone.

It is an object of the present invention to provide an optical objective of the type described consisting only of refractive components and capable of achieving good aberration correction when operating over a wide waveband at a large aperture.

According to the invention, there is provided an optical objective of the type which comprises front and rear positive lens groups axially separated by an air space, not containing any lens components, of not less than 0.75F, where F is the equivalent focal length of the complete objective, wherein the front and rear lens groups each consist firstly of a triple lens combination of three lens elements and secondly of a single lens element, the single lens element within each group being positioned on the side of the triple lens combination nearer the air space separating the two lens groups and being of shorter focal length than the equivalent focal length of the triple lens combination of the same group, whereby the respective triple lens combinations are located in the object and image spaces of the respective single lens elements in the front and rear groups.

In the above-described objective according to the invention, the said triple lens combination in each group is provided primarily to contribute towards aberration correction, while the said single lens element in each group is provided primarily to contribute towards the refracting power of the objective.

Preferably, the triple lens combination in the front lens group is approximately afocal (focal length greater than ±10F). This lens combination may conveniently comprise a cemented triplet. The lens combination in the rear lens group preferably also has a substantial focal length exceeding F, the focal length of the single element in this group being less than F. This lens combination may conveniently comprise either a cemented triplet or a cemented doublet component followed by a simple component. In each case, the triple lens element combination preferably comprises a front converging element, an intermediate diverging element and a rear converging element.

The single lens element primarily providing the refracting power in each lens group preferably consists of a meniscus element concave to the rear. In each such single element,

the curvature of the front surface is preferably at least twice and preferably at least approximately three times the curvature of the rear surface. The avoidance of extreme materials is useful to reduce difficulty in correction of primary aberrations.

A field flattening lens is preferably provided to the rear of the rear lens group, conveniently a negative simple component.

The substantial air separation between the two groups is preferably not less than about 1.0F. This large separation makes it possible to locate a reflecting component between the two lens groups, for example to fold the optical axis through any of a wide range of angles.

The objective is particularly useful for application in the field of sighting devices, and for such application a graticule may be provided to the rear of the field flattener, relatively close to the image plane. The graticule may be axially movable to suit a varying object distance.

Numerical data for two examples of optical objective according to the invention are set forth in the following tables wherein, in the radius (R) column, the negative sign indicates a surface concave to the front. The tables also give the axial separations between adjacent surfaces; in this column d denotes a lens thickness and S an air spacing. The refractive indices (μ) are given for the d-line of the spectrum. Clear apertures (C.A.) are also tabulated. Units are millimetres, but clearly the objective can be dimensionally scaled up or down.

Example 1 F = 144.94 F/No. = 0.95

R	d or S	μ	C.A.
R_1 = 307.34			152.33
	d = 31.26	1.5725	
R_2 = −173.74			151.56
	d = 9.00	1.7018	
R_3 = 173.74			147.66
	d = 19.97	1.5725	
R_4 = ∞			147.60
	S = 1.00		
R_5 = 161.57			147.60
	d = 18.68	1.5725	
R_6 = 494.54			144.69
	S = 155.36		
R_7 = 66.55			80.75
	d = 17.37	1.61375	
R_8 = 189.87			75.16
	S = 11.59		
R_9 = 59.94			60.72
	d = 15.56	1.61375	
R_{10} = −241.94			55.86
	d = 4.52	1.7552	
R_{11} = 42.32			46.06
	S = 7.80		
R_{12} = 49.78			43.64
	d = 14.06	1.7440	
R_{13} = 201.27			37.36
	S = 7.33		
R_{14} = ∞			30.79
	d = 4.26	1.7552	
R_{15} = 57.97			27.59

Example 2 F = 182 F/No. = 1.2

R	d or S	μ	C.A.
R_1 = 307.34			152.4
	d = 29.21	1.5725	
R_2 = − 224.00			151.2
	d = 12.70	1.7018	
R_3 = 140.46			146.0
	d = 26.67	1.5725	
R_4 = ∞			145.8
	S = 1.27		
R_5 = 165.04			145.3
	d = 17.78	1.61375	
R_6 = 528.32			143.0
	S = 184.18		
R_7 = 70.08			69.4
	d = 16.51	1.61375	
R_8 = 376.42			64.7
	S = 1.32		
R_9 = 102.90			61.2
	d = 15.18	1.5725	
R_{10} = − 136.58			55.7
	d = 8.89	1.7018	
R_{11} = 28.02			42.4
	d = 20.32	1.5725	
R_{12} = − 1367.54			37.1
	S = 7.35		
R_{13} = − 301.27			31.0
	d = 5.08	1.7847	
R_{14} = 66.55			28.2

Both examples have an entrance pupil of about 150 mm. diameter, and Example 1 covers an angular field of ±5 degrees while Example 2 covers a field of ±4 degrees. The back focal length in Example 1 is 6.882 and in Example 2 it is 9.57. In each case, for example when the objective is to be used in a sighting device, a plane graticule may be positioned between the rear surface of the field flattening lens and the image plane. Such a graticule will be axially movable to suit differing object distances.

For clarification, it will be understood that, in Example 1, the front lens group comprises the surfaces R_1 to R_6, the rear lens group comprises the surfaces R_7 to R_{13} and the field flattening lens comprises surfaces R_{14} to R_{15}. The triple lens combination in the front group is a cemented lens triplet defined by surfaces R_1 to R_4 and the single lens element by the surfaces R_5 to R_6. In the rear group, the single lens element is defined by surfaces R_7 to R_8 and the triple lens combination by surfaces R_9 to R_{13}. In Example 1, this triple lens combination in the rear group consists of a cemented lens doublet R_9 to R_{11} and a simple component R_{12} to R_{13}. Example 2 is similar, but the rear lens group has one less surface as the triple lens combination therein is formed as a cemented lens triplet R_9 to R_{12}.

In each example, the triple lens combinations in the front and rear groups are primarily used for aberration correction and the single lens elements to provide refracting power. This is especially true of the front lens group, where the triple lens combination is substantially afocal. Thus, in Example 1, the focal length of the triple lens combination in the front group is 2364.1, while the focal length of the single lens element is 409.08. This arrangement, wherein each group comprises a combination of three lenses primarily providing aberration correction and a single lens element primarily providing refracting power, enables aberrations of the secondary spectrum to be well corrected without the introduction of extreme lens materials which are disadvantageous to correction of the primary aberrations, especially higher order monochromatic aberrations.

Various modifications are possible within the scope of the invention. More especially, the aberration-correcting triple lens combination in the front group, while consisting of three lens elements, need not essentially be formed as a cemented triplet component.

Examples 1 and 2 are further exemplified in the Figures 1 and 2 of the drawings accompanying the provisional specification.

WHAT WE CLAIM IS:—

1. An optical objective of the type which comprises front and rear positive lens groups axially separated by an air space, not containing any lens components, of not less than 0.75F, where F is the equivalent focal length of the complete objective, wherein the front and rear lens groups each consist firstly of a triple lens combination of three lens elements and secondly of a single lens element, the single lens element within each group being positioned on the side of the triple lens combination nearer the air space separating the two lens groups and being of shorter focal length than the equivalent focal length of the triple lens combination of the same group, whereby the respective triple lens combinations are located in the object and image spaces of the respective single lens elements in the front and rear groups.

2. An objective according to claim 1, wherein the triple lens combination in the front lens group has a focal length greater than 10F.

3. An objective according to claim 1 or claim 2, wherein the triple lens combination in the front lens group comprises a cemented triplet component.

4. An objective according to claim 1 or claim 2 or claim 3, wherein the triple lens combination in the rear lens group has a focal length exceeding F, the focal length of the single lens element in the rear group being less than F, where F is the focal length of the complete objective.

5. An objective according to any of claims 1 to 4, wherein the triple lens combination in the rear less group comprises a cemented triplet component.

6. An objective according to claim 5, wherein the triple lens combination in the rear group comprises a cemented doublet front component and a simple rear component.

7. An objective according to claim 5, wherein the triple lens combination in the rear group comprises a cemented triplet component.

8. An objective according to any of claims 3 to 7, wherein the or each triple lens combination comprises a front converging element, an intermediate diverging element and a rear convergent element.

9. An objective according to any of claims 1 to 8, wherein the single lens element in either one or both of the front and rear lens groups comprises a meniscus element concave to the rear.

10. An objective according to claim 9, wherein the curvature of the front surface of the simple meniscus component is at least twice and preferably at least approximately three times the curvature of the rear surface thereof.

11. An objective according to any of claims 1 to 10, wherein in each lens group, the refractive indices of the materials of the lens elements differ from one another by not more than 0.15.

12. An objective according to any of claims 1 to 11, including a field flattening lens to the rear of the rear lens group.

13. An objective according to claim 12, wherein the field flattener is a negative simple component.

14. An objective according to any of claims 1 to 13, wherein the separation between the two lens groups is not less than F.

15. An objective according to claim 14, including a reflecting component located between the two lens groups to fold the optical axis of the objective.

16. An objective according to any of claims 1 to 15, for use in a sighting device, including a graticule positioned to the rear of the rear lens group.

17. An optical objective substantially as set forth in the tables relating to Examples 1 and 2.

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1502546 PROVISIONAL SPECIFICATION

2 SHEETS *This drawing is a reproduction of the Original on a reduced scale*

Sheet 1

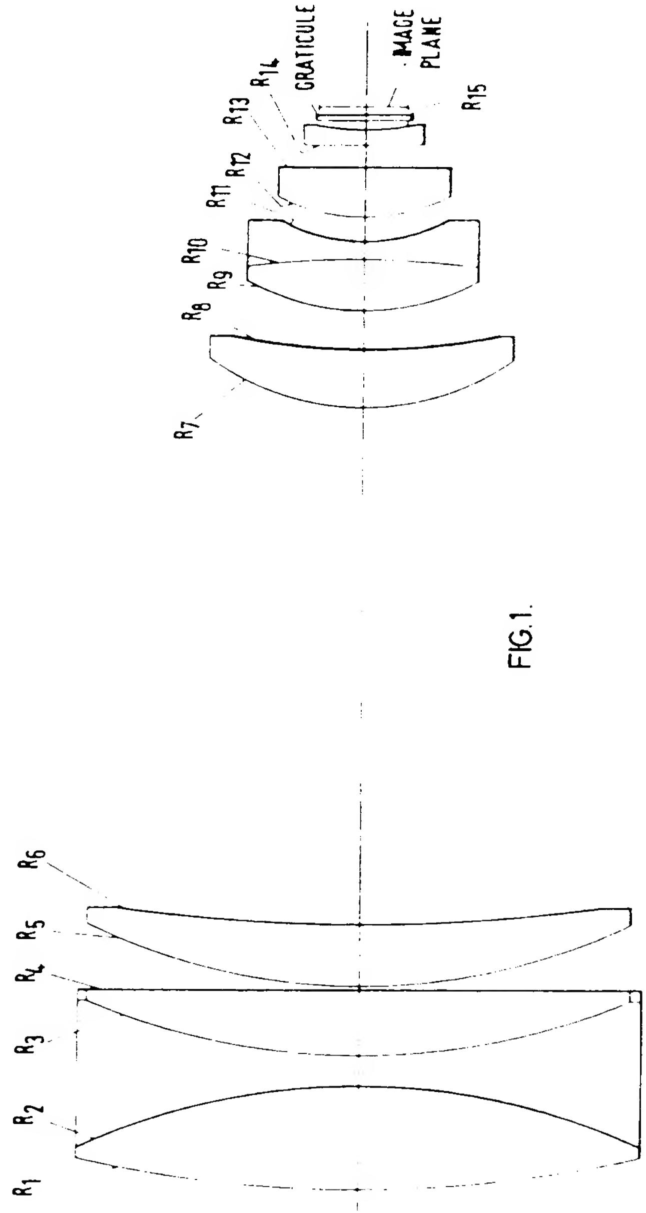

FIG.1.

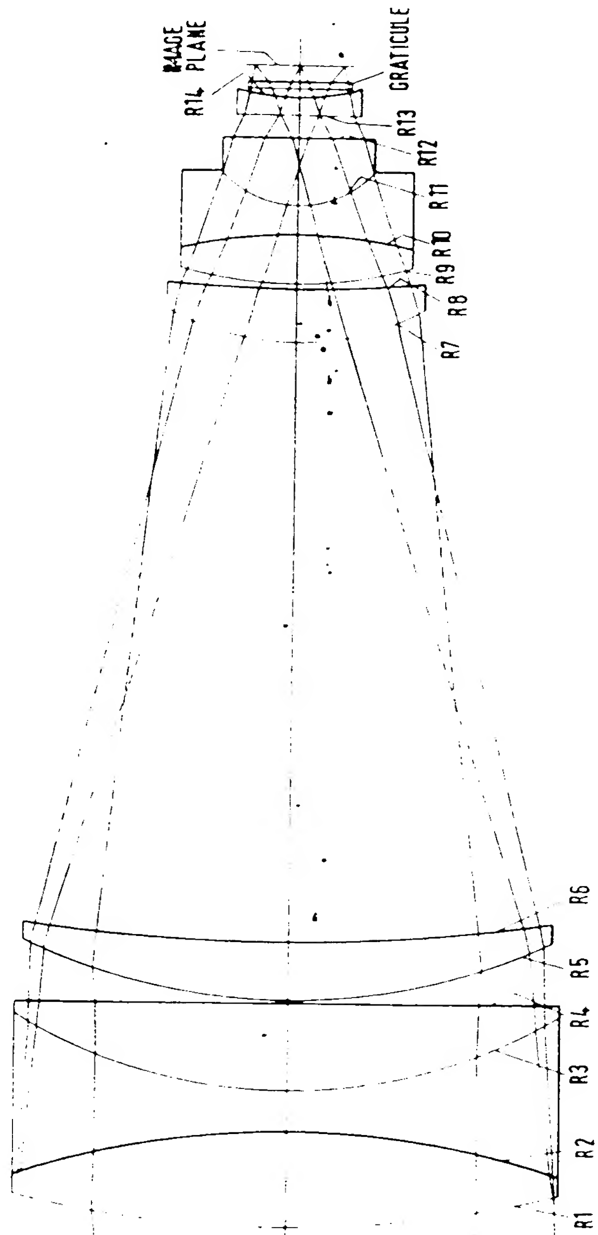
IMAGE PLANE
GRATICULE
R14
R13
R12
R11
R10
R9
R8
R7
R6
R5
R4
R3
R2
R1

FIG.2.